Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol. 3, No.5, 2013
www.iiste.org

Enhancing Environmental Integrity in the Northern Savanna Zone of Ghana: A Remote Sensing and GIS Approach.

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This research is financed by the Environmental Protection Agency of Ghana

Abstract
Land degradation has become the hallmark of developing countries whose livelihoods are directly tied to the land such as engaging in agriculture. In Ghana land degradation is an environmental challenge to farming communities as such the need to investigate the complex nature of the problem in worse affected regions of Northern, Upper East and Upper West regions. Methods used to investigate land degradation in these regions are analysis of satellite imagery, modelling of desert hazard indicators in ArcGis 9.3 software and interview of farmers using focus group discussion. Findings of the study show three main risk levels of land degradation and desertification such as high, moderate and low risks. The study concluded by proposing suitable sites for woodlot development to address land degradation and desertification problems in the study regions.
Key words: Land degradation, desertification, land cover change, woodlots, risk levels.

1 .1 Introduction

Growing demands of human society for economic development and expansion of settlements due to increasing population is driving unprecedented land use changes that result in land degradation, for instance, soil erosion, nutrient depletion, salinity, water scarcity, pollution, disruption of biological cycles, and loss of biodiversity (UNEP, 2006). These anthropogenic activities are associated with varying degrees of environmental threats that adversely affect the biophysical components of the earth surface (Blowers *et al*, 2008). In most African countries such as East Africa, scientists working on sustainable land use have confirmed human induced land degradation as negatively affecting and food security (Slegers and Stroosnijder, 2008). Ghana had 35% of its land under threat of desertification especially Upper East, Upper West and Northern Regions since the 1960s and 1970s (Kwarteng, 2002). Environmental and socio-economic appraisal of parts of the savanna vegetation such as the Kpone catchment agro-ecological zone in Northern Ghana shows a land use ration of almost 100%, which is intensive use of land that does not allow land to fallow with the view to regain lost soil fertility in the Guinea savanna ecological zone, hence, the persistent problem of land degradation (Dedzoe, *et al*, 2002). Land degradation in Northern Ghana has rendered large tracts of croplands which were once fertile currently unproductive as such contributing to depleting income and food sources. As a result of this land degradation, grasslands, woodlands and forests are being lost while natural water bodies are drying up due to prolonged droughts and deposit of sediments into water courses. Accelerated degradation has compelled the Environmental Protection Agency to initiate measures to implement a National Action Programme to combat drought and desertification in these regions. Combating droughts and desertification requires assessment of the woodland vegetation cover in the three regions to determine total acreage/hectares of woodland cover types and degraded areas in order to determine appropriate sites for woodlot development.

1.2 Evidence of land degradation

Evidences of land degradation are documented either based on physical observation of land cover changes by people using the land or change detection analysis of satellite data to explain land degradation. Change detection refers to monitoring land surface change over time using repetitive coverage and consistent data generated from satellite images (www.ciesin.org/TG/RS/chngdet.html). Satellite multi-spectral data sets are cost effective and reliable for estimating forest and woodland cover changes (Jones *et al*, 2008). Application of remote sensing image analysis techniques to vegetation cover assessment using multispectral satellite data has demonstrated the

immense potential of detecting, quantifying, monitoring and mapping vegetation changes in the Upper East region of Ghana (Owusu, 2009). Satellite imagery obtained from Advanced, Very High Resolution Radiometer covering savanna areas of Africa including the Upper East and West regions and the Northern Region show that these regions have the highest occurrence of vegetation fires as such the land surface is exposed to degradation (Kugbe and Henmi, 2009). These fires have contributed to soil erosion and leaching as the bare soil surface is exposed to agents of erosion such as rain water and wind (Kugbe and Henmi, 2009). NDVI image analysis produced by CERSGIS shows evidence of remarkable land degradation in Upper East, Upper West and Northern Regions (CERSGIS, 2010). Furthermore, participatory GIS and remote sensing investigations in Bolgatanga and Talensi- Nabdam districts of northern Ghana reveal decline of healthy vegetation from 1990 to 2004 resulting in about 600km^2 of land being degraded, hence, the decline in commercial food crop production (Agyeman, 2007).

1.3 Indirect causes of land degradation

Indirect causes of land degradation are mainly policies, economic factors and population issues that contribute to land degradation. Government policy failures and misdirected policies have in certain cases indirectly resulted in deforestation in developing countries (Norman and Myers, 1991). In Sub-Saharan Africa, rapid population growth and poverty constitute the main driving forces of change in forest land use (Lambin, *et al*., 2003). Rapid population growth coupled with poverty was responsible for the conversion of woodland and forest areas to cropland and pasture fields in southern Burkina Faso (Ouendraogo *et al*., 2010). Ghana's population growth is equally responsible for land degradation in Upper East and West Regions (Songsore, 1976). Even though population growth rates of 2.3% and 2.5% are below the national average of 3.0%, these regions have the fastest population growth rates in Ghana (Songsore, 1976). A more recent study by Millar *et al*, (2004), associates severe land degradation to high population density in the Upper East Region. Apart from human population pressure on the environment, high animal population density also poses land degradation problems as cattle population density in the Upper East Region, for example, appears to be the highest at 103 and 77 per km² in Navrongo and Bawku districts respectively (Wassai, 2000). In areas where cattle population is high excessive overgrazing has reduced the biological productivity and carrying capacity of the land (Gyasi, 1997). Furthermore, most African economies are heavily reliant on agriculture and natural resources for their GDP, national food needs, employment and export revenues that require clearing forest lands, hence, the persistent land degradation challenges (Mutangadura, 2007).

2.4 Direct causes of land degradation

Direct land use activities such as agricultural expansion, wood extraction and infrastructure development have collectively contributed to loss of forest and woody vegetation covers (Geist and Lambin, 2002). In most developing countries charcoal and firewood are considered as the basic energy sources yet inefficiency in charcoal and firewood production pose a challenge for sustainable land use in African countries (Wood Energy and the Environment, 2008). Fuelwood extraction, selective logging by commercial firms and extraction of construction materials indeed contributed to land degradation (Backeus *et al*, 2006). In Ghana, clearing of woody vegetations for agriculture and wood energy exploitation have contributed to 12% of the vegetation cover being converted from grass to cropland an indication of land degradation in Northern Ghana (Braimoh, 2006). In the Northern region massive destruction of sheanut trees in the White Volta river basin which is 30km from Tamale to prepare land for bio-fuel plantations in Kusawgu contributed much to de-wooding of large areas as heavy agriculture machinery was used to prepare the land for Jatropha curca farming (Bakari, 2007). Besides agriculture as a direct driver of land degradation, small scale mining activities in Bolgatanaga and North East of Talensi –Nabdam contributed to severe land degradation in these areas (Agyeman, 2007).

2.5 Effects of land degradation

Disturbances of forests and woodlands can push ecosystems beyond their resilient points resulting in adverse hydrological and surface energy imbalances (Garcia, 2008; Helmer, *et al*, 2000)). Tree canopy removal affects the hydrology of forest ecosystems by, for example, causing the water table to rise in areas receiving high annual rainfall leading to soil leaching and poor vegetation growth in certain cases (Roy, 1998). In relation to climate change, trees are considered to provide carbon sinks and clearing of trees and woody vegetation contributes to the release of carbon dioxide (stored in trees) into the atmosphere with consequences of global warming (Searchinger *et al*, 2008). Greenhouse gas emissions from trees and soil account for approximately 2 billion tons of annual global CO_2 released into the atmosphere due to deforestation (FAO, 2005). In Sub-Saharan Africa, destruction of forests have the potential of increasing soil carbon in the atmosphere to cause global warming (Vagen, *et al*, 2005). Land degradation does not only affect the biophysical environment but also disrupts the livelihoods of millions of people as activities such as hunting and gathering, are becoming difficult, leading to

violent conflicts (World Wide Fund, 2007). Land degradation in Northern Ghana has resulted in fragile environmental conditions coupled with harsh climatic conditions of droughts and periodic floods (Care, 2008a). In other instances persistent drought has manifested in chronic malnutrition and wide spread poverty (Destombes, 1999). The upper regions particularly experience rapid weather changes which have severe impact on water storage capabilities as a result worsen the water stress situation in northern communities (Osei, 1996). A major non biophysical effect of land degradation in Northern Ghana is migration of farmers from degraded regions to rural areas of the Brong Ahafo Region, that has more fertile agricultural soil unlike the impoverished agricultural lands at the origin of migrants as evidenced by low crop yields coupled with unreliable rainfall resulting in food insecurity problems (Van der Geest, 2004). Any further worsening of desertification in northern Ghana would in no doubt affect the economy of Ghana adversely as much of the food and animal products come from these regions (Kwarteng, 2002).

3.0 Study regions

The northern region is located within latitude 10º 39' 0" N and 8º 6' 30"N and longitude 2 º 35' 30" W and 0º 27' 30" E covering an area of 70, 383 Square Kilometers. The region shares boundaries with Upper East and West regions to the north, Brong Ahafo region to the east and La cote d' Ivoire to the west. The land is generally low lying except the north-eastern where the Gambaga escarpment is found.

Table 1. Geographic Coordinates of Northern, Upper East and West Regions

The Upper East region is located within latitude 11º 9' 30" N and 10º 39' 0" N and longitude 1º 34' 30" W and 0 º 3' 0" W. The region shares boundaries with Burkina Fasso to the north, Togo to the east, Upper West region to the west and Northern region to the south. The region occupies a land area of 8,842 Square Kilometres the smallest administrative region in Ghana. The upper west region is located within Latitude 11 º 0' 0" N and 10 º 0' 0"N and Longitude 3 º 0'0"W and 2 º 0' 0"W. The region covers a land area of 18,476 Square Kilometres. The terrain is characterized by series of wide plateaus composed of Birrimian and post Birrimian granites rising to heights of between 200m and 435m for example, at Kaleo hill. The region shares boundaries with Northern region to the North, Upper East Region to the east and Burkina Faso to the north and west.

4.0 *Methods*

Three methods were used to assess land degradation and determine possible sites for woodlot development such as classifying satellite images, modeling desertification hazard potentials and interviewing respondents to know the extent to which they are willing to allocate their lands for woodlot development. Landsat ETM+ 2010 imagery was geo-referenced and classified using the supervised maximum likelihood algorithm to determine land cover types in the regions. After classifying the images training sites were selected for ground thruthing to check accuracy of classified imageries. Land degradation assessment was done by modelling GIS data indicator layers of Vegetation, Climate, Soil and Land Use maps in ArcGIS 9.3 to show extent of land degradation by assigning weights to the data layers. High value weights assigned showed high level of degradation while lower value weights showed less degradation (Table 2).

Table 2 Indicators used and assigned weights.

In the surveyed communities farmers were interviewed using focus group discussion method regarding prevailing environmental conditions, what their preferences/criteria are regarding site selection for woodlot development in sampled communities as in Table 3.

Table 3 Sampled Communities

5.0 Results

5.1 Land cover changes and determination of possible sites for woodlots

Land use and land cover analysis for Northern region (Figure 1) show distribution of land cover types such as close savanna woodland vegetation, open savanna woodland, dense herbaceous/grassland with scattered trees, Grass/herbaceous cover, bares areas/built up areas and water bodies.

Figure 1 Landsat ETM+ 2010 classified image map for Northern Region

Close savanna woodland covers 1557221.76 ha of the regions land area thus, 22.3% of the landscape in 2010. Open savanna woodland vegetation constitutes 1339258.32 ha thus 19.1%. Dense herbaceous/grassland with scattered trees was 1516856.4 ha (21.7%) of the surface area, Grass/herbaceous cover occupies 802172.52 ha (11.4%) while bare soil/built up areas was 1692252.36 ha (24.2%) which is the highest land use/ cover in the entire region. The close and open savanna woodland vegetation includes national parks and forest reserves that have improved quality of the vegetative cover compared to Upper East and West Regions. Given the degrading land cover, potential areas for woodlot development identified include East and Central Gonja Districts where agriculture production is not a major competitor to land availability for woodlot development. Further

exceptionally good sites for woodlot development are Kpandai District specifically Old Makango and Lonto close to the Volta Lake where irrigation farming is possible. The exceptions include Bunkpurugu Yanyoo and Tamale Municipal where there is high competition for land for agriculture due to high population density resulting in general decline in soil fertility. While farmers are willing to allocate parts of their land for woodlots they are cautious not to use their land for any project that would not bring them income.

In the Upper East Region close savanna woodland forms 47811.96 ha of the land area which is only 5.4% of the vegetative cover. Open savanna woodland was 88290 ha, thus, 10% of the land area, dense herbaceous/grassland with scattered trees was 158479.92 ha which is 17.9% of the land area and Grass/herbaceous cover forms the highest proportion of vegetation cover which is 315164.52 ha, thus, 35.7% of the regions vegetation. The expanse of grass

Figure 2 Landsat ETM+ 2010 Classified image for Upper East Region

land vegetation with 270156.96 ha (30.6%) of bare soils/built up surfaces altogether show that more than 60% of the vegetation cover in the region is degraded as such a major environmental and livelihood challenge to the people. Water which is essential for agriculture and domestic use occupy's only 2707.92 ha. (0.3%) of the regions land area hence the risk of water stress is high. Suitable areas identified for woodlot development include Choo in Bolga Municipal, Tongo and Gorogu in Talensi-Nabdam district and the eastern wildlife corridor along the red and white volta where no farming activity takes place. Further communities are Kazugu in Kassena Nankana west district, and Tamne river area in Garu/Timpane district. Areas found unsuitable for woodlots include Bawku municipal where the population density is high as a result intensive cultivation of land makes it difficult to succeed with any woodlot venture. While the possibility exists for woodlot development farmers are concerned about persistent annual wildfires and free range cattle grazing activities that have the potential to destroy trees.

The vegetative land cover statistics for Upper West Region is not much better comparing the Northern and Upper East Regions. Close savanna woodland vegetation occupy's 243743.4 ha of land area, open savanna woodland extends 35300919 ha, Dense herbaceous/grassland with scattered trees forms 710333.2 ha. Grass/herbaceous cover forms 317708.28 ha of the regions vegetation cover

Figure 3 Landsat ETM+ 2010 Classified image for Upper West Region

Bare soil/built up areas that are symptomatic of no vegetation cover hence a sign of sever degradation constitutes 298898.64 ha. Such degraded areas are of little importance for agriculture a major occupation in the region. The extent of degradation coupled with other biophysical factors gives the indication that the region has high potential for woodlot development. A possible site for woodlot development is Funsi in Wa West District, as Funsi has vast land and water bodies that can be used for tree seedling irrigation. Some unsuitable areas identified are populated settlements where intensive agriculture and grazing is common such as Nandom.

5.2 Desert hazard indicators

The desertification hazard map of Northern Ghana (Figure 4) shows various levels of desertification risks such as water stress, physical loss of soil nutrients, soil erosion, salinization and poor vegetation cover that have been categorized into three risk levels of high, moderate and low risks.

High risk zones: High risk areas fall in the Guinea and Sudan savanna ecological zones in the North, Upper East and West regions. In the Northern region, district such as Tolon, Chereponi and Saboba to mention a few, for example, fall in the high risk areas. In Upper East region almost the entire region falls in the high risk area except districts such as Paga and Sandema. In the Upper West region high risk districts include Lambushi, Lawra, Jirapa and Wa. High risk areas normally have low annual rainfalls of 600 – 700 mm coupled with high evapotranspiration of 1951 – 2150 mm per annum due to high annual temperatures of 25° - 40°C. Soil quality is categorized as poor to moderate comprising tertiary sand and alluvial deposits. Soils of this kind have rock fragments between > 20 and shallow soil depths of < 20 cm. Soil drainage is moderate to poor. The vegetation cover is characterized by savanna vegetation that is highly prone to fire during the dry seasons. Poor soil conditions make it difficult for smooth cultivation of crops.

Moderate risk zones: Moderate risk desertification hazard in Northern region can be associated with districts such as Zabzugu, Wulensi and Kpandai. In Upper East region, Tongo, is an example of a low risk district. In Upper West Region, Funsi and Wechiau districts are examples of moderate risk areas. Characteristic features of moderate risk areas include moderate total annual rainfall range of 700mm to 800mm and annual temperature range of 30 – 40 °C per annum with annual evapotranspiration figures of 1801 – 1950 mm. Soil depth is normally more than 100cm and rock fragments are less than 20% characterized by parent materials derived from shale, schist, limestone, granite marbles and sand stone. Over cultivation of the land in moderate risk areas has rendered soil nutrients poor as such unable to support healthy crops.

Figure 4 Desertification hazard map of Northern Ghana

Low risk zones: The low risk desert hazard areas are limited in extent and mostly found within forest reserves and national parks such as the Mole national park. High amounts of annual rainfall in Ghana are experienced in this part of the country at a range of 800 to 900 mm coupled with average temperature of 30 – 40°C and low annual evapotranspiration of 1651 – 1800 mm. Parent materials that form the soils are produced from shale, basic conglomerate, gneiss and siltstone. Though the low risk areas are desirable for biodiversity and livelihood support this state of environment is fast disappearing hence the need for woodlot development to avert high risk desert hazards in the future.

6.0 Discussion

Analysis of satellite imagery for the three regions has clearly shown where woody vegetation exists and where it does not exist for effective action plan on woodland development. A similar study in the Barekese catchment of Ghana to detect change in land use and cover between 1973 and 2000 show close canopy forest decreased by 43%, open canopy forest decreased by 32% while grassland/open areas increased by 70% (Boakye *et al*., 2008). Creating woodland/forest reserves in identified areas may improve the habitat of animals in these ecological zones and also improve biodiversity and the micro climate of the areas such as reducing hot winds that blow in these areas (CERSGIS, 2010).

The desert hazard map for Northern Ghana shows spatial variation in risk levels that have possible implications for the respective regional developments. According to the National Development Planning Commission's medium term development policy framework for 2010 to 2013, development has to focus on sustained micro economic stability, accelerated modernization of agriculture and effective natural resources management all aimed at poverty reduction and reducing income inequalities (NDPC, 2010). For this reason, any comprehensive development plan should focus on improving and coping with existing soil, climate and vegetation conditions.

7.0 Conclusions

In conclusion high risk desert prone zones are worse affected and most food in-secured places as rainfall is variable and unpredictable for crop cultivation coupled with poor soil fertility. The lack of water and poor nutrient soils also make it difficult for sufficient and healthy growth of grass for free range animals. It would have been appropriate to under take irrigation farming but this has not been developed. Identification of suitable areas for woodlot development is one sure way of addressing land degradation. By this approach, moderate desert prone risk areas would be stabilized and further developed to low risk desert lands for improved biophysical environment and enhancement of the social and economic livelihoods of peasant farmers in these regions.

Acknowledgement

The authors acknowledge the Environmental Protection Agency of Ghana for providing funding for the study. We are also grateful to Mr Henry Baffoe, Mr Emmanuel Tetteh and Mr George Owusu all staff of the Centre for Remote Sensing and Geographic Information Services, at the University of Ghana, Legon for providing assistance during composing of the study maps.

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Table 1. Geographic Coordinates of Northern, Upper East and West Regions

Regions	**Latitude**	**Longitude**
Northern	10° 39′ 0"N - 8° 6′ 30"N	2° 35′ 30"W - 0° 27′ E
Upper East	11° 9′ 30"N - 10° 39′ 0"N	1° 34′ 30"W - 0° 3′ 0"W
Upper West	11° 0′ 0"N - 10° 0′ 0"N	3° 0′ 0"W - 2° 0′ 0"W

Table 2 Indicators used and assigned weights.

Indicator	Data layers	Classes	Assigned
Soil	Slope (%)	0 - 4	1
		4	2
		>16	3
	Parent material	Good	1
		Moderate	2
		Poor	3
	Soil texture	Heavy	1
		Medium	2
		Light	3
	Fragment cover (%)	<20	1
		20-60	2
		>60	3
	Drainage	Well	1
		Moderately Well	2
		Poor and Excessive	3
	Depth (cm)	>100 (Deep)	1
		20-100 (Moderate)	2
		<20 (Shallow)	3
	Organic Matter	>4.3 (High)	1
		2.2 - 4.3 (Medium)	2
		<2.2 (Low)	3
	Iron Pan (within 50 cm from	Not Present (NP)	1
		Present (P)	3
Climate	Precipitation (mm)	1700 - 2200	1
		1200 - 1700	2
		700 - 1200	3
	De Martonne aridity coefficient	17.94 - 33.53	1
		33.53 - 49.12	2
		49.12 - 64.71	3
	FAO aridity coefficient	0.326 - 0.76	2
		0.76 - 1.195	2
		1.195 - 1.63	3
Vegetation			
		Close savannah	2
		Open savannah	2
		Shrub thicket	3
		Grassland	3
Managemen	Land use types		
		Built-up /bare lands	3
		Open/close/shrubs	1
		Grassland	2

Table 3 Sampled Communities

Upper East Region	
District	**Communities**
Bolga Municipal	Choo
Talensi nandam	Tongo, Gorogu, Shiega
Bongo	Bongo, Bogoro, Adaboya
Garu Tempane	Shishi, Gozesi, Tempare, Tsutsruga, Sakote, Tamne
Bawku Municipal	Missiga, Kulungugu, Mognori
Northern Region	
District	**Communities**
Sawla Tuna Kalba	Kalba, Sawla, Nyoli
Tolon kumbugu	Singa, Jinkrom, Lungbunga, Wantugu
Savelugu Nantom	Nabogo, Kadia, Nyong-gama
East Mamprusi	Nalerigu, Nagbo, Langbinsi, Namash
Bunkpurugu Yunyoo	Jimbale, Nakpanduri, Bibago-konkon
Nanumba north	Nakpa, Taali, Pusuga,Bincheratanga
Tamale municipal	yong, Dalum
Kpandai	Gulubi, Loloto, Old Makongo
Yendi Municipal	Kulkpene, Bachalbado
Upper West Region	
District	**Communities**
Lawra	Lawra
Sissala West	Gwollu
Sissala	Tumu
Wa	Wa
Wa West	Funsi

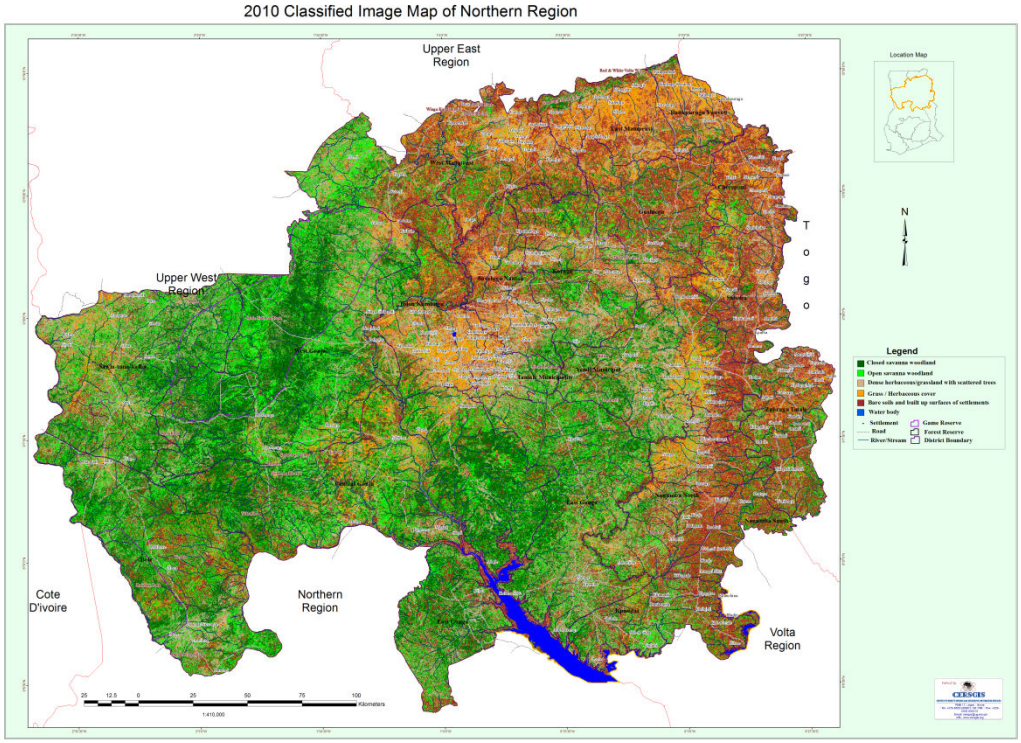

Figure 1 Landsat ETM+ 2010 classified image map for Northern Region

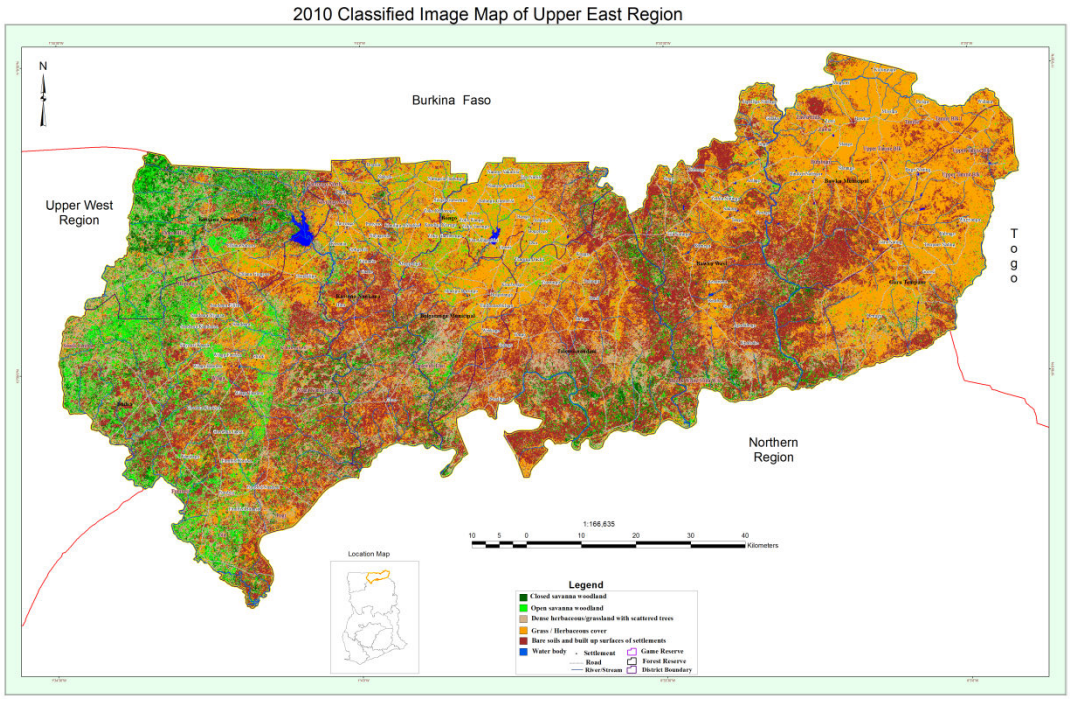

Figure 2 Landsat ETM+ 2010 Classified image for Upper East Region

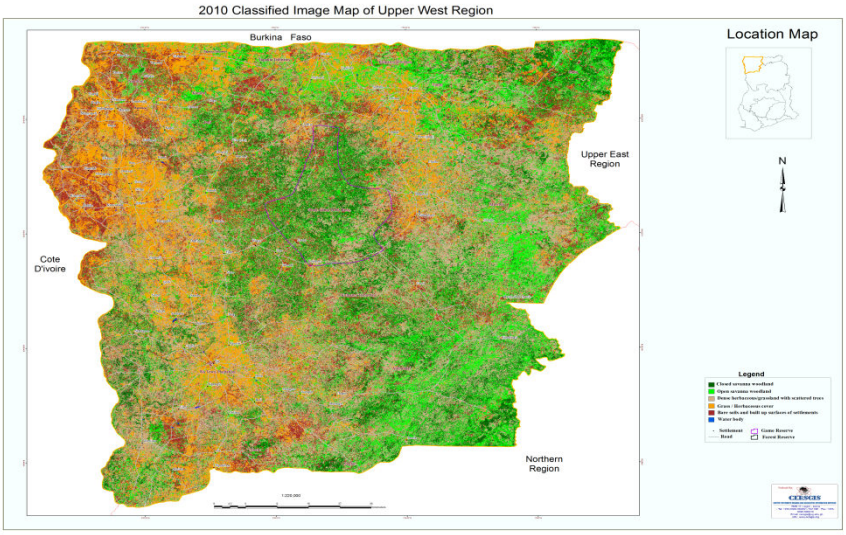

Figure 3 Landsat ETM+ 2010 Classified image for Upper West Region

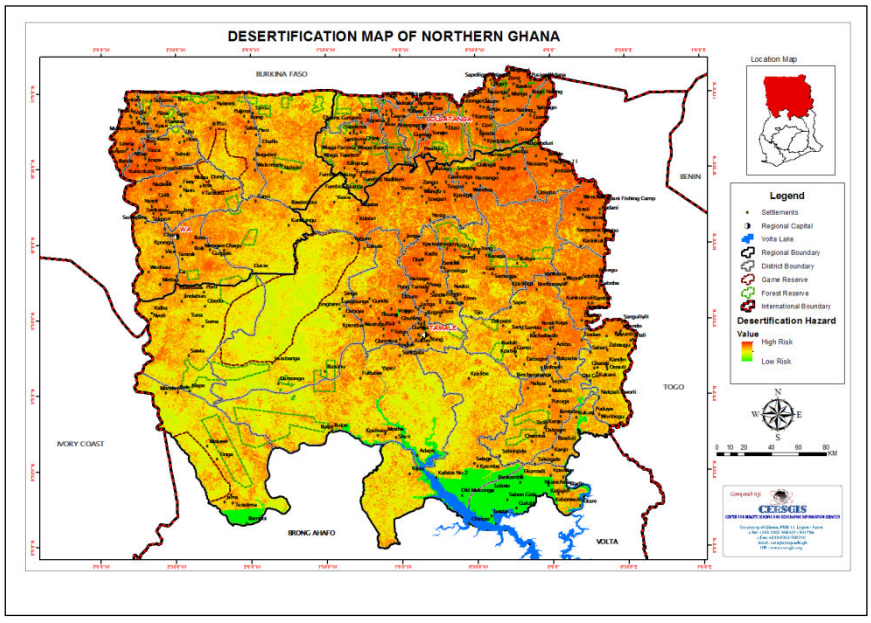

Figure 4 Desertification hazard map of Northern Ghana